The Story of our Universe

A presentation by

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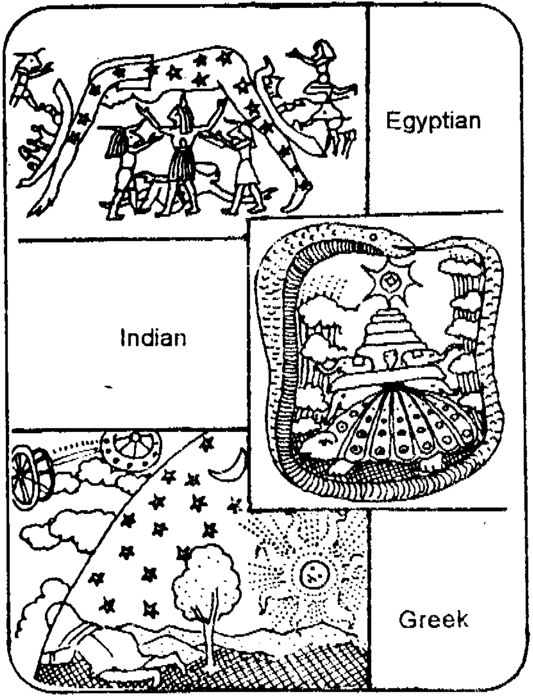
The Universe in imagination

The sky overhead has fascinated and awed the human race for ages. Man has been trying to understand the sun, moon and stars since his beginning. He perceived the earth to be standing still and the celestial objects as moving around it. With this in mind he imagined many a picture of the Universe.

For the Egyptians the sky became goddess *Nut*. *Ra*, the sun-god, and the planets sailed across the star-studded body of Nut. In our mythology the earth rests on a golden platter which sits on an elephant's back which stands on a tortoise. The tortoise is really Lord Vishnu sleeping on



the coiled serpent Vasuki. Many still believe it and think that earthquakes are caused by Vasuki's movements.

Greeks held the earth to be a flat disk and the sky a dome-shaped roof over it. They believed that the stars are fixed to this roof. Beyond the sky-roof were the machinery turning the Universe and the demons driving these. Many such stories came up in all civilizations around the ancient world.

Sky - the time-keeper

Man kept on watching the heavenly bodies and noted the regularities. The sun moved swiftly overhead and was easy to follow. The time between two risings of the sun became a *day*. The moon was less regular, but it changed its shape daily. From one 'full' moon to another marked out a *month*. The star pattern at sunset changed only slightly from day to day. It took a rather l-o-n-g time for the starry sky to change and repeat itself. And that was a *year* for man. During a year the sun rose and set 365 times and the moon showed its beautiful round face a dozen times.

All these movements gave man a nice clockwork to measure time with ! By watching the stars that hugged the horizon just before the sun-rise or right after the sunset he learned to reckon the seasons. The sky told him when to start on a hunt and when to head back home; when to sow and when to harvest. Sky - the object of wonder - became a clock and an almanac for the mankind.

The Earth-centred Picture

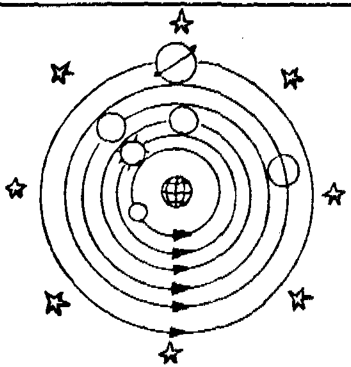
With growing experience man's ideas about the Universe became more developed. It took the shape of a science - man's earliest science. Slowly a model of the Universe emerged where everything revolved around the earth, but in definite orbits. Beyond the moon, sun and planets lay a crystal sphere and the stars remained fixed on it.

The geo-centric model reached its pinnacle with Greek astronomer Claudius Ptolemy (90 - 168 AD). With its mathematical and physical representations the model could explain most observations, including the retrograde (backward) motion of the planets. It could also predict the positions of the celestial objects in advance. But it was quite complicated and it failed in some instances.

Yet for the first time it brought together all available knowledge in the field and gave a coherent picture. Hence it was widely accepted and faced no serious challenge for over a thousand years.

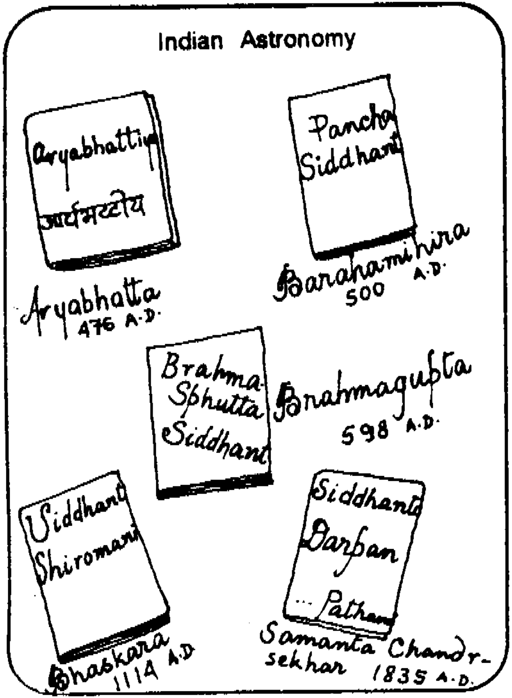
Astronomy in India

The ancient civilizations of India, China, Greece, Egypt and Mesopotamia were quite advanced in astronomy. These dated back to some 5000 years from now. Unfortunately, the written records of India's early astronomical



Geo-centric model

Ptolemy



acomplishments are scanty. The available materials point to much important work carried out between the 5th and 12th century AD.

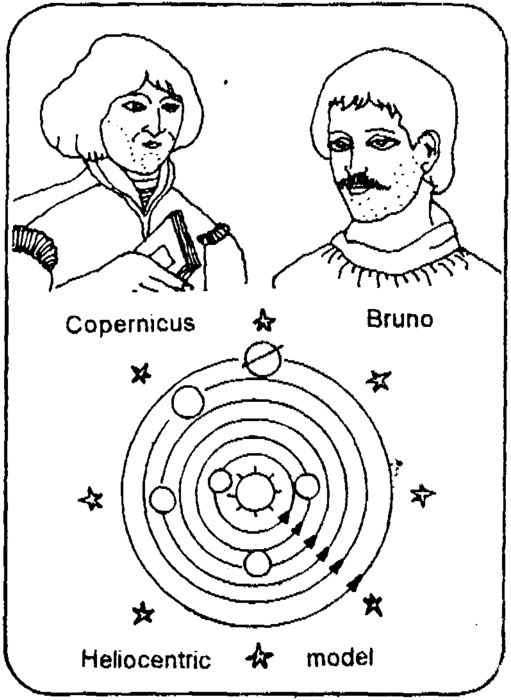
Among the important Indian astronomers of this period were: Aryabhatta (476 AD, Pataliputra), Varahamihira (500 AD, Ujjain), Brahmagupta (598 AD, Punjab), Bhaskar (1114 AD, Maharastra). Aryabhatta had an idea of a sun-centred model but did not find any support for it. He had understood the real cause of the eclipses and explained the same in his major work, the *Aryabhattiya*. Varahamihira was the other pioneer astronomer of that period and was one of the *Nava Ratna* of the Gupta Empire. His major manuscript was the *Pancha Siddhanta*.

Traveller Al-Beruni describes Brahmagupta as the greatest mathematician of India who probably introduced the 'zero'. He thought of a force of attraction of the earth and recorded the same in his work, the *Brahmasphuta Siddhanta*. Bhaskara was an accomplished astronomer and mathematician. He is known particularly for his contributions to Algebra in which he was far ahead of his European contemporaries. He had developed his own method for calculating the planetary positions. He had put together his astonomical and mathematical theories in his *Siddhanta Siromani.*

Astronomical work continued to flourish in India with several persons working in various parts of the country under the patronage of the local rulers. While many were concerned primarily with panchang refinements, others came up with novel ideas and approaches. Samanta Chandra Sekhar, known popularly as Pathani Samanta, (1836 - 1904) was one such astronomer in Orissa who had put forward a model similar to that of Tycho Brahe. The accuracy of his observations, compiled in his book - *Siddhanta Darpana* , was remarkable especially as these were gathered using simple home-made implements. The Jantar Mantars, massive stone and masonry astronomical instruments, built by Maharaja Sawai Jai Singh during the 18th century around North India are very well known.

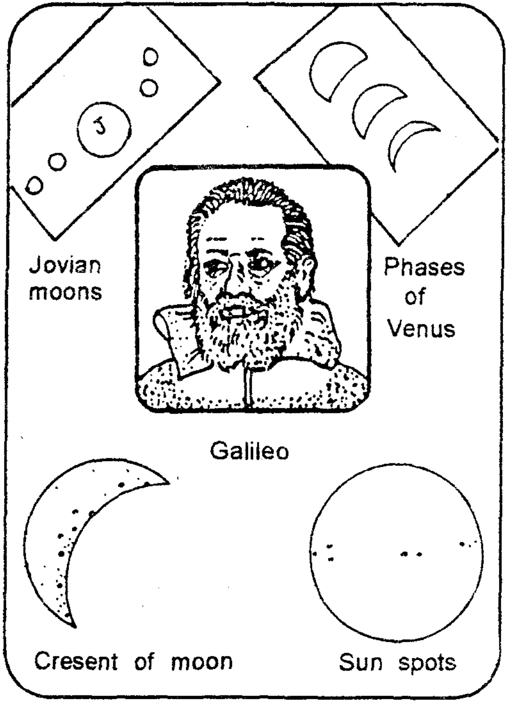
The Sun-centred Universe

As more and more data got compiled, newer pictures of the Universe started emerging. Polish astronomer Nicolaus Copernicus (1473 - 1543) proposed a model where the Sun came to occupy the centre of the 'Universe'. Earth and the other planets went around the sun in his picture. Only the moon was left to circle the mother earth. Stars could not be understood fully yet and were left, as before, in a sphere beyond. Much earlier Greek astronomers Aristarchus and Hipparchus (300 BC) and Indian astronomer Aryabhatta (5th century AD) had suggested such a sun-centred picture; but the geo-centric model ruled supreme on the strength of the great Greek philosopher Aristotle.



Now the well-argued views of Copernicus raised new doubts about it. Copernicus was on his death-bed when his views were published. The church authorities banned the book immediately saying that it opposed the holy scriptures. However, the new spirit could not be stiffled totally. Among many followers of this view was an Italian - Giordano Bruno (1548 - 1600). In propagating the Copernican view Bruno challenged the church openly and had to pay for it with his life. He was burnt at the stake on February 17, 1600.

That was also the time of another great Italian scientist Galileo Galilei (1564 - 1642). His powerful observations, logic and experiments made the heliocentric view very strong. He was the first person to look at the sky through a telescope and to observe craters on the moon and dark spots on the sun. This went against the religious belief that everything in the sky (or the Heavens) was perfect and unblemished. He also showed that there were satelites going around Jupiter 'like a mini solar system'. All these helped to shake up the foundation of the old dogmatic views. But the final proof of planets moving around the earth came from his telescopic observation of the phases of Venus. Waxing and waning of venus, like that of the moon, could happen only if it was placed between the earth and the sun.



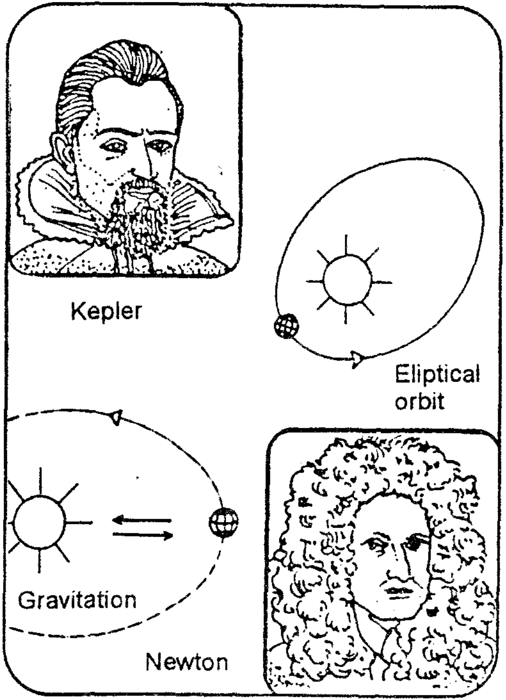
Galileo too suffered in the hands of the church and his writings were banned. (Only recently, 300 years later, the church formally acknowledged its mistake). But he had helped the sun to stand firmly at the centre. More than that he had ushered in the age of experiment and logic for science.

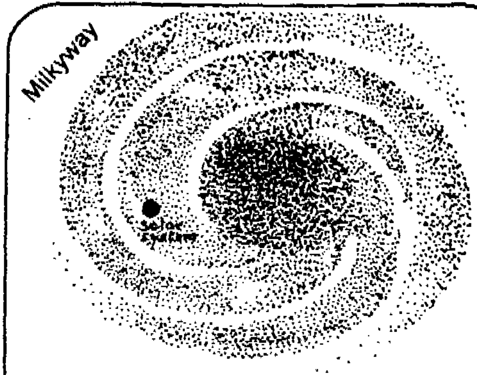
German astronomer Johannes Kepler (1571 - 1631) further improved the sun-centred model. He formulated elliptical orbits for the planets and the laws of planetary motion. This simplified the picture greatly but at the same time explained almost everything known at that time.

Isaac Newton (1642 - 1727) was born in England in the same year when Galileo died. His work revolutionised the world of science in many ways. He explained that the force of sun's attraction, gravitation, made the planets move around it. In a way he elevated the sun from merely being in the physical centre to a position of authority over the planets. The family of the planets and the sun came to be known as the *solar system*. The earth was thus completely dethroned from its position of ruling the Universe !

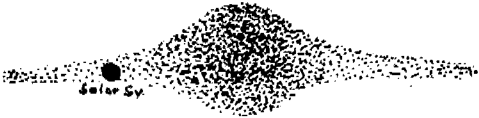
The Solar System

Man slowly began to understand the stars which were so far left guarding the outer edges of the solar system. Around the year 1917 it came to be known that the twinkling stars are





Top view



Lateral view

nothing but distant suns. And the many many stars we see, including the sun, belong to a huge grouping called the Milky Way. Such star groups came to be known as *galaxies* in general. By 1925 man understood that the Universe is composed of many many many such galaxies of various shapes and sizes spread over a vast and seemingly endless space. And what was even more amazing was that these innumerable galaxies appeared to be moving away from one another at greater and greater speeds depending on their distance from us.

Our home, the Milky Way galaxy, appeared to be a spiral with many arms. From the edge it looked like a flat disc with a bulging centre. The width of this immense disc was one lac light years (1 light year (ly) = about 10 lac crore kilometres) ! The solar system was only a small dot towards the outer edge of this disk and the earth smaller still.

Let us just look at some figures to appreciate the scale. The width of our solar system is about 1200 crore km (0.0012 ly) while that of the earth is only 13,000 km (0.000,000,0013 ly). Therefore, if we put 12 crore solar systems side by side they will cover a single width of our galaxy ! And it will take 1 lac crore tiny earths to mark a line across the solar system. If we were to compare the areas they occupy the numbers will simply be staggering : about 2 crore crore crore crore (2 with 28 zeroes or 2×10^{28}) earths will be needed to form a lawn over our home galaxy !

Yet it was not a very long time back when man thought the earth to be supreme. In the changed picture even the sun is nothing very special in the milky way. Even our galaxy is one among the many galaxies spread over the gigantic Universe whose size (radius) we now estimate to be at least 1000 crore (10 billion) light years. It may appear that compared to this vast Universe there is nothing special about our tiny earth. To the astronomers it may be so. But for most of us it has a pride of place. It is........*OUR HOME..... a line in our address.*

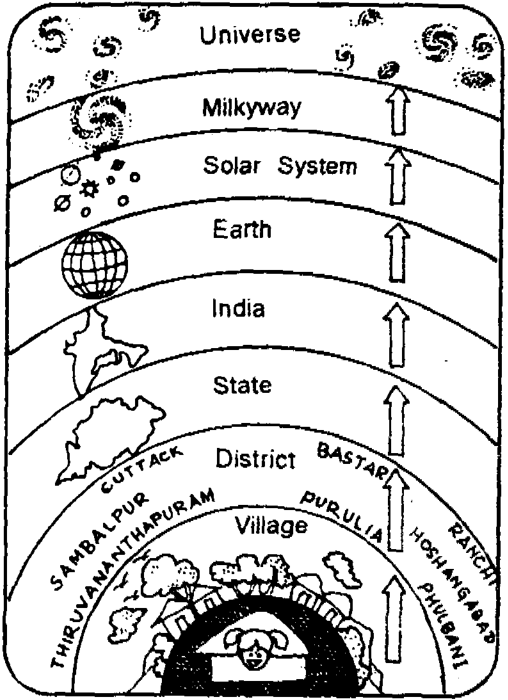
Our Address

Yes, everyone has an address, a unique place in the Universe. To find me you need to know ....

.....my name,....my home number,.....the street I live on,......my village or town,......my district,....my state.......and, perhaps, my country at the most (if you are from another country).

But what if you are from another planet ?...another stellar system ? .....another galaxy ? Should we not add these to make our address complete ? In that case our address will end as...

....the Earth,...Solar System, ...Milky Way Galaxy,... and, of course,... THE *UNIVERSE*.



The Universe we see

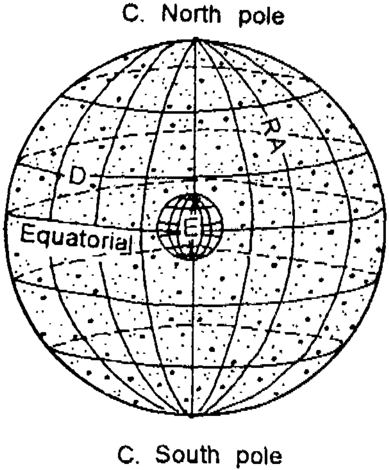
To man the Universe has always been the space and objects overhead. But how did he learn so much about the nature of our sun, planets, galaxy....and the Universe itself ? It may sound surprising, but what had started it all is something we do today too.

It is simply gazing at the fascinating star-studded sky above and wondering about it. Curiosity and interest that drives us today in that direction also played its part on the early man's mind. These are some gifts all human beings are born with. The foundation laid through watching the sky matured in time to the science of Astronomy. The observations, early and recent, helped us know and understand as we do today.

The Celestial Sphere

The sky appears to be a giant sphere only a half of which we can see at a time. This imaginary sphere surrounding the earth was named the *Celestial Sphere (khagol mandal)* by the early observers. The stars seemed to be fixed inside this sphere and moved along with it *without changing* their relative positions. To help in identifying the stars man put them in groups, called the *constellations*, and imagined many shapes and figures to describe them.

*To remember the star posi*tions and to measure their movements man also imagined line markings in the sky, much like the poles, equator, longitudes and latitudes on the earth. These are called, respectively, the *celestial poles*, *celestial equator, right ascension (RA) and declination*. These were easily formed by extending or projecting the earth lines / points towards the sky. These measures, particulaly the RA and declination, help us in identifying every point in the sky.



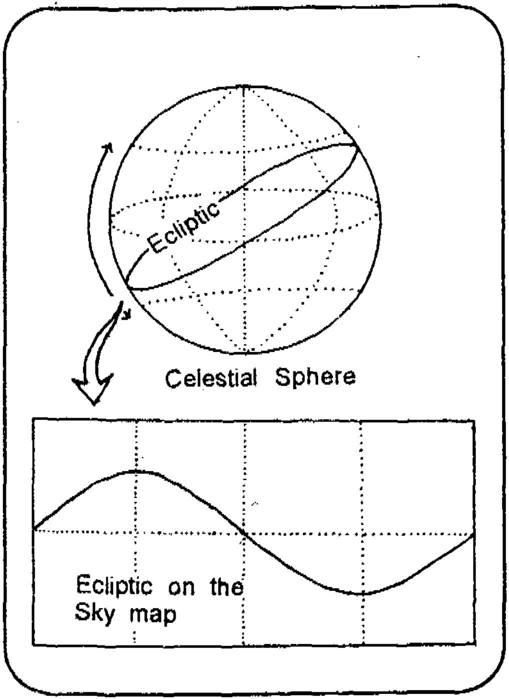
Khagol Mandal

Travellers in the Sky and Their Path

Even a casual observer notices that sun, moon, stars and all seem to go around us once in a day, rising in the east and setting in the west. We call this the *apparent daily motion* of the celestial sphere. *Apparent* - because this is really the result of the earth's own west to east rotation. A careful observer will, however, notice that the sun seems to move among the fixed stars very slowly from *west to east* cutting a regular path across the sky. This movement - known as the *apparent annual motion* - is so slow that it takes the sun about 365 days to complete a round. This too is *apparent* because earth's going around the sun makes it seem so.

We said earlier that this is the basis of man's year. It also has some interesting implications for us, the star-lovers. If the sun remained fixed we could never see the stars around it! Sun helps us by moving away almost unnoticeably at the rate of about *one degree per day*. This makes the stars seem to rise 4 minutes earlier every day or 2 hours earlier every month.

Man has recognised sun's movements from the earliest times



and has identified the stars lying along its path. This path on the sky-globe or the celestial sphere has been named the *ecliptic* or the (line of) *zodiac*. Ecliptic because eclipses of sun and moon were seen to take place on or near this line. Or zodiac because constellations thought to resemble animals marked this path. Twelve such constellations, called the *zodiacal constellations* or the *signs of zodiac*, have been recognised as mile-stones to measure sun's movements through the year.

The moon travels along this path too, but at a much faster pace. It covers the ecliptic in 27 days or about 13 degrees in a day. This is a speed we can notice quite easily and man has devised other markers along the zodiac to measure it. The 27 *nakshatras* *(asterisms)* serve this purpose in the Indian system.

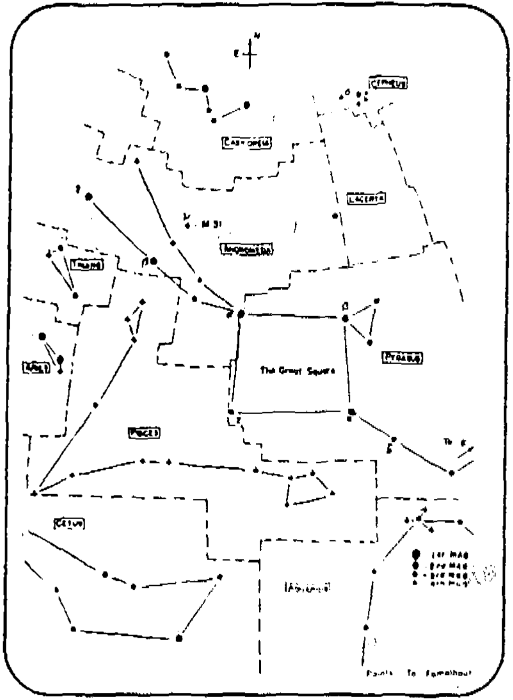
This is also the path along which the planets move, but in very irregular manner. Their speeds vary and sometimes they even appear to move backwards. In fact, the name planet suggests *wandering star*. Yet others imagined special powers with the planets to move as they want to. But today's astronomy can explain all these quite simply. In a way astronomy grew as a result of trying to understand their complex movements and of trying to predict their positions in advance.

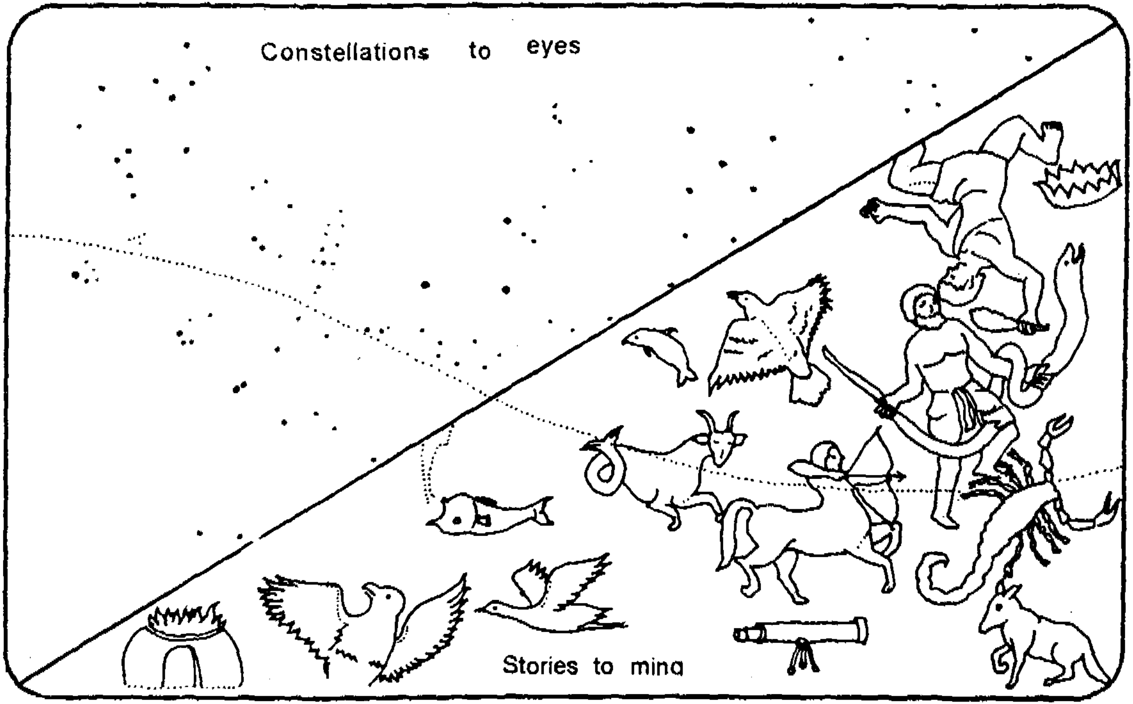
Once man charted out this path in the sky he used it well. He could tell the day (*tithi*), month and season by following the sky travellers. Some even tried to make predictions about man's life from it and many even do it today. But we know for certain that there is no basis for it.

Charting the By-standers

The larger and faster moving objects in the sky commanded a greater attention from man. All this time the more numerous but smaller twinkling objects stood quietly in the background. They did fascinate man but he was not quite sure what to make of them. Yet these stars helped him a lot by staying fixed in their places and serving as pointers and milestones for the celestial travellers. Just imagine what a nightmare would it be if the stars kept on changing their places every night !

Man showed his appreciation for the stars by counting them, naming them, making up stories and shapes about them. Then he set about taking stock of it all. The whole sky now stands divided into 88 sectors like the countries on the earth. Each area in the sky is named after a constellation and the stars named or numbered according to it. The amateur star gazers, however,s still look for the shapes by joining the brighter stars with imaginary lines.




Constellations to eyes
Stories to mind

Maps of the sky have been drawn to guide us around. From the co-ordinates, RA and declination, that we talked of earlier we can spot these stars. To make matters easier we also have maps according to the months and hours. With a little bit of practice we can easily recognise our 'heavenly' friends. Once we become familiar with the more prominent constellations they will act as our pointers and help us locate their other friends in the sky.

And we in India are lucky too. Our place on the globe is such that we can see all the major constellations and bright stars. Clear skies through much of the year and not too cold weather help us enjoy the picture overhead that changes by the hour and by the season.

Sky, the Great Storybook

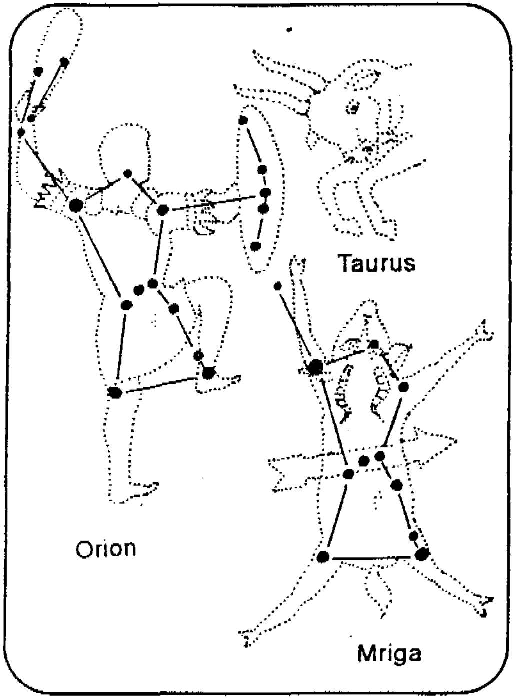
To help him in remembering the paths in the sky man grouped the stars. To remember the groups easily he drew figures for them and, perhaps, to make it more interesting he made up many stories about them. The stories differ from country to country, region to region, culture to culture.

But for all humanity the sky is a great storybook, one full of pictures too. It is ever open to one and all. All one needs to do is to look up to see the stars and let the pictures fill the mind !

Want a taste ? Let us take the example of Orion or *Kalpurush* , one of the most prominent constellations in the sky. It is visible in the evenings in winter and early morning hours in summer. Since the celestial equator passes through its middle, at least a part of it is visible from every place on the earth.

In most countries it is pictured as a hunter holding a club and a shield. With a sword hanging from his belt he is ready to face the charging bull (constellation *Vrisa* or *Taurus*) in front. Following him are his two dogs *canis major* (with the star *Sirius* or *Lubdhak*, the brightest star in our sky, as its gleaming tooth) and *canis minor* . In some stories the shield in his hand is replaced with a lion skin or a dead lion.

In our country there is yet another story. The four major stars of this constellation are imagined as the four hooves of a deer. The faint group of three stars, asterism *Heka* or *Mrigasira*, marks the deer's head.



And the deer itself represents Brahma. According to the legends Brahma felt a passion for his daughter Rohini, the female deer represented by the star *Aldebaran* or *Rohini*, and pursued her in the guise of this deer. The gods would not allow such a sin to be committed and created a very powerful hunter (constellation *Mrigavyadha* or canis major) who slew the deer with a special arrow. The arrow which pierced the deer's body is called the *Isu Trikanda* and can still be seen as the line of three stars at the middle of the constellation. What is most interesting is that a hunter in one story becomes the hunted in another.

Most stories like this link the major stars and star-groups nearby and lead us on to explore around the sky with even greater interest.

True Stories in the Sky

The sky does not tell us fictions only. Man has learnt many things from the sky. The sky told our ancestors when to go out and when to return home; when to sow and when to harvest.... As time passed the sky led to the birth of our earliest science, the *science of astronomy*. It also spurred us on to develop this science further along with mathematics.

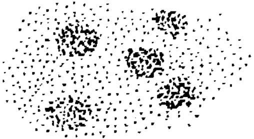
The story about the earth standing still in the middle of the Universe came from watching things moving overhead. The changed picture with the sun at the centre came from a closer reading of the same sky. Along with it came a revolution in the method of science and established a role for experiment and logic.

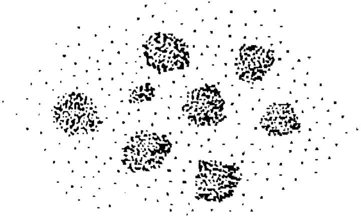
With the solar system accounting for all the moving bodies in the sky, man started wondering about the 'fixed' stars. Slowly he started seeing newer pictures in the sky : *Galaxies* packed with crores and crores of stars, floating like islands in the endless space, each like a Universe on its own. And man kept on wondering as to what the stars were and what secrets did this seemingly infinite Universe hold.

The Life of a star

Overhead we see a variety of stars. They differ in colour, brightness and in many other ways. It is something like a market place where we see all sorts of people - young, old, tall, short.... Similarly, the star varieties represent their age and the stage in life. Yes! Stars do age. And to age they must be born and die too.

Stars are born, often in groups, within vast clouds of gas and dust called *nebulae*. When such a cloud patch gets a jolt, compression sets in. As the pressure inside rises the gas cloud gets hotter and starts to glow faintly. The pressure and temperature keep on rising and a time comes when


Interstellar gas cloud


Condensation

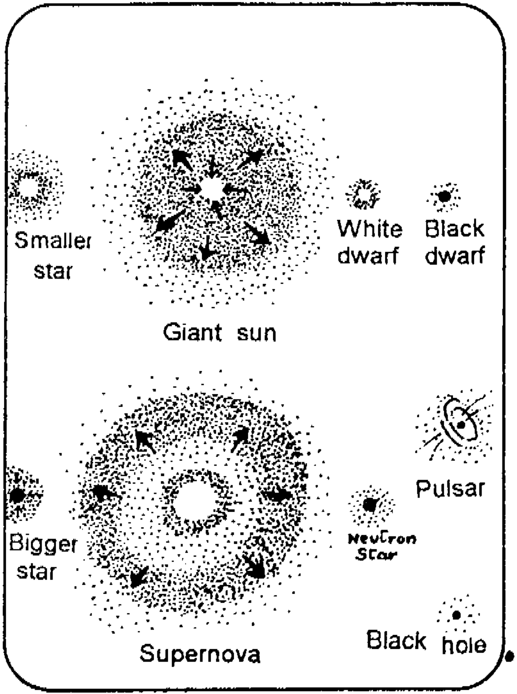
Protostar

the enormous heat causes the gas atoms to fuse. This nuclear fusion reaction releases a very large amount of energy and makes the star shine for the rest of its life.

A young star is very hot, bright and it generally gives out bluish light. As its age increases its fuel stock goes down and it starts to cool. Along with this its colour changes to white to yellow to orange, and finally, to red. All the while it keeps getting bigger and bigger and becomes a *red giant* . The fate of the star after this differs depending on its size. The dividing line is 1.4 times our sun's mass - a figure known as the *Chandrasekhar limit* after its discoverer, the India-born scientist Prof. S. Chandrasekhar (1910 - 1995).

The *smaller stars* keep on cooling and expanding beyond the red giant stage. Its outer layers slowly drift away and a small core glows white. This too cools with time getting dimmer and dimmer ; redder and redder. On further cooling the *red dwarf* stops emmitting light and the star dies. The body of the dead star, called a *black dwarf*, floats around unseen as a lump of coal, cold and dark.

The larger stars burn up their fuel faster causing their cores to



collapse. As a result the outer gas layers cave in onto the hot core triggering a gigantic explosion - the *supernova* explosion. So much light (and energy) is given off that it may be visible during the day-time. All the heavy elements known to us are formed *only* during such violent star deaths. And some of it goes into making our own bodies too !

This disperses all but the dense core which keeps on collapsing attaining densities beyond imagination. Such extremely small but super-dense stars do not generally give out visible light and exist in the form of *neutron stars* or *pulsars*. The still larger stars end up as such heavy neutron stars that no radiation can escape their enormous gravity. These un-seeable heavy weights are what we call *black holes*.

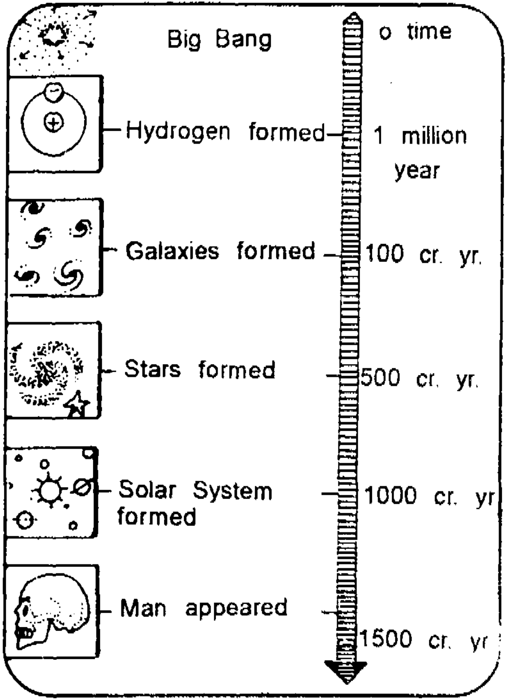
One thing we must keep in mind is the time-scale. Stars take crores of years to form and die. And these keep on happening all the time somewhere or the other in the Universe. The events we see from the earth today have happened very very long time back. Since they are very far away light takes so long to reach us. Even tonight we can look upto the sky and see many things like the birth place of a star (the *Orion nebula* in Orion's sword) or a supernova remnant (the crab nebula in Taurus) or the many stages of star life in the Kalpurush. There we can see a red giant *star Ardra (Betelgeuse) and a bright blue-white supergiant star Rigel.*

The Story of the Universe

Can the sky stell us this story too? Well, why not? So far it has done so well both in fantasy and reality that we come to expect a lot from it. And luckily for all it does not let us down.

With bigger and better instruments astronomers kept on improving their view of the sky. They found the Universe to have many galaxies within it and that these galaxies are moving away at great speeds as if they were being driven by a tremendous explosion. Working backwards, they figured that such an explosion - the *big bang* - must have taken place about 1500 crore (15 billion) years back. This theory is now generally accepted and says that in the beginning the whole Universe was compressed into a single point. Time and space came into being at the moment of big bang.

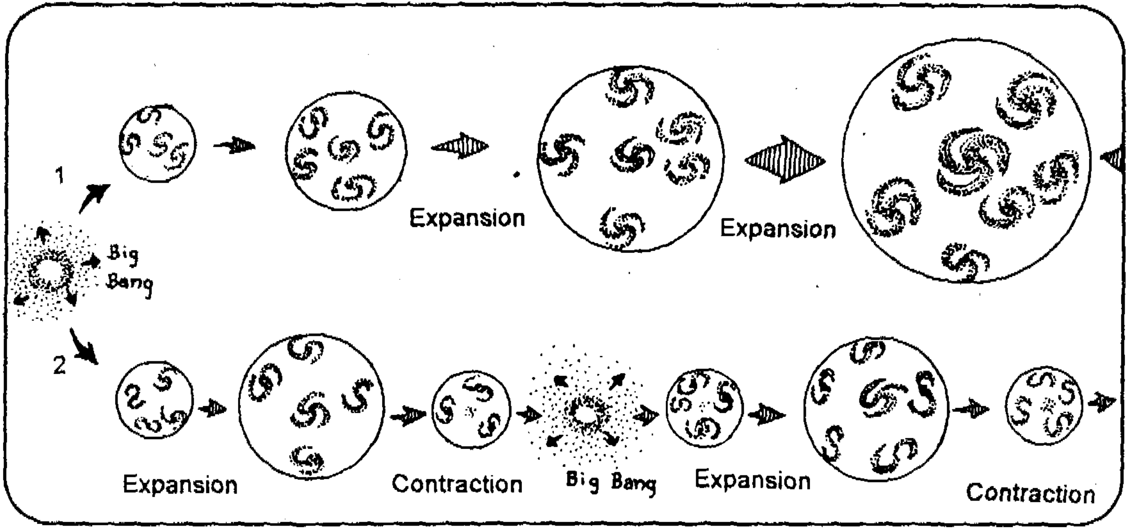
As space expanded, the dispersed matter cooled slowly and condensed in patches. Later on these formed galaxies, stars, planets....and even us. But it took about 10 lac years for the first galaxies to form. Our sun was born 1000 crore (10 billion) years after the big bang or about 500 crore years from today. Man, by comparison, is very young or only about 1 crore years old.



This great expansion still continues. It is believed that it will continue till the time when gravitational attraction overtakes it. All matter will then start coming closer and closer, moving faster and faster with time, till everything is compressed to a point again. This *big crunch*, as some people nickname it, will happen with such force that another explosion, a new big bang, will follow. All history will repeat again. And perhaps, again and again and..... The cycles of expansion and compression will keep on repeating.

There is yet another view, however less accepted, that the Universe will go on expanding for ever. More and more matter will keep on being created all the time to fill in the new space. And the question about the future of the Universe still remains - will it stop expanding some day or not ? And after that what ?

In a way it is a good thing too that questions do remain. If we were absolutely sure of all answers we will stop reading the 'sky book' or keeping our minds open about things around. We might even stop wondering and questioning altogether. *And without questions can our knowledge ever grow ?*



The Universe is defined to include everything that we can think of. From a conce ptual view point there is no outside to it. All space, time and matter form part of the Universe.